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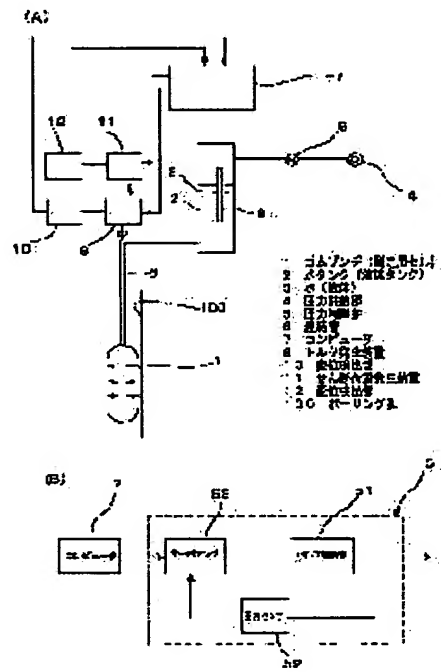
(54) METHOD AND DEVICE FOR TESTING LIQUEFACTION AND DYNAMIC PROPERTY OF GROUND IN SITU BY UTILIZING BOREHOLE

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a method and a device for testing the liquefaction and dynamic properties of ground in situ by utilizing a borehole, which can provide dynamic deformation properties with respect to a repeated load on a soil layer in an arbitrary position in the ground by using the simple method.
SOLUTION: The repeated load is imposed on a test object soil layer of a hole wall of the borehole 100 which is provided in the ground, so that displacement of the hole wall can be measured. In particular, this method and this device are characterized in that the repeated load is imposed alternately on a plurality of areas J1 and J3 in the direction of a hole axis, so that a shear force in a direction crossing the hole axis can be made to act on an intermediate soil layer J2 in an alternately repeated manner. Additionally, a static load is imposed on the soil layer J2 in which a repeat test is performed, so that strength can be measured.



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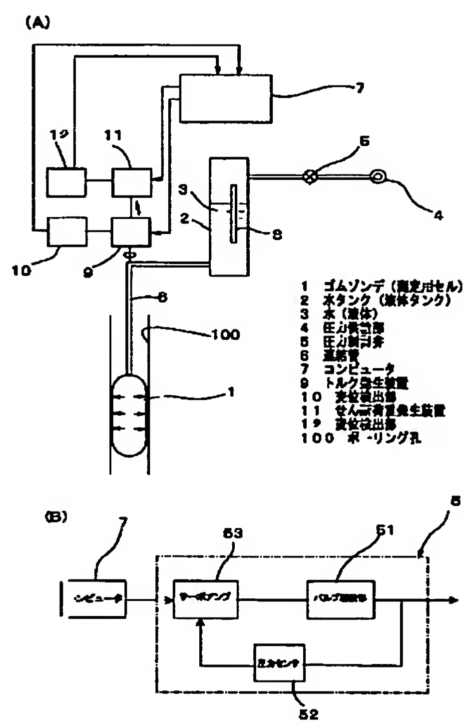
(54)【発明の名称】　ボーリング孔を利用した原位置での地盤の液状化および動的特性試験方法および試験装置

(57)【要約】

【課題】地盤内の任意の位置の土層の繰り返し荷重に対する動的な変形特性を簡易な方法で得ることができるボーリング孔を利用した原位置での地盤の液状化および動的特性試験方法および試験装置を提供する。

【解決手段】地盤に設けたボーリング孔１００の孔壁の試験対象土層に繰り返し荷重を載荷して孔壁の変位を測定する。特に、孔軸方向の複数の領域Ｊ１，Ｊ３に交互に繰り返し荷重を載荷することにより、中間土層Ｊ２に孔軸と交差する方向のせん断力を交互に繰り返し作用させることを特徴とする。また、繰り返し試験を行った中間土層Ｊ２に静的な荷重を載荷して強度を測定する。



【特許請求の範囲】

【請求項１】　地盤に設けたボーリング孔の孔壁の試験対象土層に繰り返し荷重を載荷して孔壁の変位を測定し地盤の動的特性を求めることを特徴とするボーリング孔を利用した原位置での地盤の液状化および動的特性試験方法。

【請求項２】 ボーリング孔の孔壁の孔軸方向の複数の領域に交互に繰り返し荷重を載荷することにより、荷重の載荷領域の中間土層に孔軸と交差する方向のせん断力を交互に繰り返し作用させることを特徴とする請求項１に記載のボーリング孔を利用した原位置における地盤の液状化および動的特性試験方法。

【請求項３】　繰り返し試験を行った中間土層に静的な荷重を載荷して強度を測定する請求項２に記載のボーリング孔を利用した原位置における地盤の液状化および動的特性試験方法。

【請求項４】ボーリング孔の孔壁の一つの領域に交互に振動または繰り返し荷重を載荷し、繰り返し加重の大きさ，振動または繰返し回数および変位の関係から、地盤の動的特性を知る請求項１に記載のボーリング孔を利用した原位置での地盤の液状化および動的特性試験方法。

【請求項５】　繰り返し荷重は、孔軸と直交する方向に載荷される圧縮荷重と、孔軸を中心とする回転方向に載荷されるねじりせん断荷重と、孔軸と平行方向に載荷されるせん断荷重の３つの荷重のうちの一つ、または少なくとも２種類の荷重を組み合わせた組み合わせ荷重である請求項１または４に記載のボーリング孔を利用した原位置での地盤の液状化および動的特性試験方法。

【請求項６】　地盤に設けたボーリング孔内に挿入されると共に圧力媒体の圧力によって孔壁を押圧する測定用セルと、該測定用セル内の圧力媒体の圧力を周期的に変動させることが可能な圧力調整手段と、前記孔壁の変位を検出するための変位検出手段と、を備えていることを特徴とするボーリング孔を利用した原位置での地盤の液状化および動的特性試験装置。

【請求項７】測定用セルはボーリング孔の孔軸方向に沿って孔壁を押圧する複数の室に区分され、圧力調整出段は複数の室内の圧力媒体に交互に繰り返し圧力を加える請求項６に記載のボーリング孔を利用した原位置での地盤の液状化および動的特性試験装置。

【請求項８】圧力調整手段は、中間室を隔てて上下の室には交互に繰り返し圧力を加え、中間室には静的な圧力を加える請求項７に記載のボーリング孔を利用した原位置での地盤の液状化および動的特性試験装置。

【請求項９】　測定用セルを孔壁に密接させた状態で測定用セルに孔軸回りに繰り返し荷重を加えるトルク発生手段と、該トルク発生手段によって加えた繰り返し荷重による孔壁の回転変位を検出する変位検出手段と、を備えていることを特徴とする請求項６に記載のボーリング孔を利用した原位置での地盤の液状化および動的特性試験装置。

【請求項１０】　測定用セルを孔壁に密接させた状態で測定用セルに孔軸と平行方向に繰り返し荷重を加えるせん断荷重発生手段と、せん断荷重による孔壁の軸方向変位を検出する変位検出手段と、を備えていることを特徴とする請求項６または９に記載のボーリング孔を利用した原位置での地盤の液状化および動的特性試験装置。

【発明の詳細な説明】

【０００１】

【発明が属する技術分野】本発明は、地震荷重，交通荷重、機械荷重等の繰り返し荷重が作用した場合の地盤の原位置での特性を検査するボーリング孔を利用した地盤の液状化および動的特性（強度，変形特性）試験方法および試験装置に関する。

【０００２】

【従来の技術】従来の地盤検査は、所定の深さまでボーリングをし、ボーリング孔内に測定用セルとしての検出ゾンデを降ろし、検出ゾンデを膨らませて孔壁に水平荷重を載荷し、荷重に対する孔壁の変位から地盤の静的な強度および変形特性を検出するようになっていた。

【０００３】

【発明が解決しようとする課題】しかし、従来の地盤検査では静的な特性を検出しているだけで、地震荷重，交通荷重，機械荷重等のような繰り返し荷重に対する地盤の強度や変形特性といった動的特性の評価をすることができなかった。地震の際には、地盤に加わる力が静的には破壊しない大きさであったとしても、徐々にあるいは急激に歪みが大きくなって破壊に至るものと考えられ、繰り返し荷重に対する地盤の特性を調査することはきわめて重要である。地震の際には地盤内には水平，上下およびねじり方向に複雑な力が作用するものと考えられ、このような複雑な力が作用した際の原位置での地盤の動的な特性を知ることはきわめて重要であるにも拘わらず、従来は原位置の地盤内で測定し評価する方法が確立されていない。

【０００４】従来の液状化の判定方法としては、たとえば、地盤全体の特性傾向を判定するもの（特開平７－３７６０号参照）、地震発生時に液状化を検知するもの（特開平７－１０９７２５号公報参照）等があるが、いずれも地盤中の土層そのものの動的特性を直接的に試験するものではなかった。

【０００５】土層自体の繰り返し荷重に対する動的な特性を知る方法としては、現在、ボーリングして乱さない状態での土のサンプルを採取して、これを試験室に持ち込んで土質試験をして求めている。しかしサンプルを乱さない状態（自然に堆積しているそのままの状態）で採取すること自体が非常に困難であるばかりでなく、採取したサンプルは地下の圧力がかかった状態でないこともあって、実際の自然状態での特性を求めることは不可能である。また、非常に締まりのない砂層あるいは礫など

を混入する土層、砂礫など粒径の大きい土層または風化岩、軟岩などの場合は乱さない状態でのサンプリングも不可能であり、したがって室内での土質試験は不可能である。以上から現状では非常に限られた条件での特性しか直接的に求めることができないのが実情である。

【0006】本発明は、地盤の繰り返し荷重に対する動的な変形特性を直接知ることの重要性に鑑みてなされたもので、その目的とするところは、乱さない状態での土のサンプルを必要とすることなく、原位置での地盤の動的な強度および変形特性を簡易な方法で得ることができるボーリング孔を利用した原位置での地盤の液状化および動的特性試験方法および試験装置を提供することにある。

【0007】

【課題を解決するための手段】上記目的を達成するために、本発明のボーリング孔を利用した原位置での地盤の液状化および動的特性試験方法は、地盤に設けたボーリング孔の孔壁の試験対象土層に繰り返し荷重を載荷して孔壁の変位を測定し地盤の動的特性を求めることを特徴とする。特に地盤の液状化についても知ることができる。ここで、繰返し荷重とは、周期的に変動する荷重全体を含める意味で、比較的振動数が高い変動荷重（振動）から、手動でも操作できるようなゆっくりした変動荷重も含まれる。動的特性とは、繰り返し荷重を加えた際の荷重と変位の関係そのものであり、たとえば、繰返し荷重の大きさ，繰返し回数および変位の関係から変形特性を把握し、降伏荷重と破壊荷重といった強度および変形係数を求めたり、これらの結果を系統立てて解析をすることで土層の動的な特性を評価できる。

【0008】特に、ボールリング孔の孔壁の孔軸方向の複数の領域に交互に繰り返し圧縮荷重を載荷することが効果的である。このようにすれば、荷重の載荷領域の中間土層に揺れと孔軸と交差する方向のせん断力を交互に繰り返し作用させることが可能となり、土層に対して地震の際と同様の力を加えることができる。繰り返し試験を行った中間土層はもっともダメージを受ける部分であり、この部分に静的な圧縮荷重を載荷して静的な強度を測定すれば、どの程度ダメージを受けているか、その度合いを知ることができる。また、ボーリング孔の孔壁の一つの領域に交互に振動または繰り返し荷重を載荷し、繰り返し加重の大きさ，振動または繰返し回数および変位の関係から、地盤の動的特性を知ることもできる。繰り返し荷重は、孔軸と直交する方向に載荷される圧縮荷重と、孔軸を中心とする回転方向に載荷されるねじりせん断荷重と、孔軸と平行方向に載荷されるせん断荷重の3つの荷重のうちの一つ、または少なくとも2種類の荷重を組み合わせた組み合わせ荷重である。

【0009】本発明のボーリング孔を利用した原位置での地盤の液状化および動的特性試験装置は、地盤に設けたボーリング孔内に挿入されると共に圧力媒体の圧力によって孔壁を押圧する測定用セルと、該測定用セル内の圧力媒体の圧力を周期的に変動させることが可能な圧力調整手段と、前記孔壁の変位を検出するための変位検出手段と、を備えていることを特徴とする。測定用セルはボーリング孔の孔軸方向に沿って孔壁を押圧する複数の加圧部を有し、圧力調整手段は複数の加圧部に交互に繰り返し圧力を加える。測定用セルは複数の室に区分されて加圧部を構成し、圧力調整出段は複数の室内の圧力媒体に交互に繰り返し圧力を加える。圧力調整手段は、中間室を隔てて上下の室には交互に繰り返し圧力を加え、中間室には静的な圧力を加える。測定用セルを孔壁に密接させた状態で測定用セルに孔軸回りに繰り返し荷重を加えるトルク発生手段と、該トルク発生手段によって加えた繰り返し荷重による孔壁の回転変位を検出する変位検出手段と、を備えていることを特徴とする。測定用セルを孔壁に密接させた状態で測定用セルに孔軸と平行方向に繰り返し荷重を加えるせん断荷重発生手段と、せん断荷重による孔壁の軸方向変位を検出する変位検出手段と、を備えていることを特徴とする。

【0010】

【発明の実施の形態】以下に本発明を図示の実施の形態に基づいて説明する。

実施の形態1

図1（A）は本発明の実施の形態1に係る地盤の液状化および動的特性試験装置の模式図である。この地盤の液状化および動的特性試験装置は、地盤に設けたボーリング孔100内に挿入されると共に圧力媒体としての水3などの液体が満たされた測定用セルとしてのゴムゾンデ1と、ゴムゾンデ1内の水3の圧力を周期的に変動させる圧力調整手段としての圧力制御弁5と、ゴムゾンデ1からの圧力による孔壁の変位を検出するための変位検出手段としての変位センサ8と、を備えている。

【0011】図示例では、水3は地上の水タンク2内に貯留され、水タンク2内のヘッドスペースに圧力供給部4から高圧気体を供給して水タンク2内の水3を加圧しており、圧力制御弁5はこの高圧気体の圧力を制御している。場合によっては、高圧気体の制御ではなく、水圧を直接調整する構成としてもよい。また、水タンク2とゴムゾンデ1は連結管6によって連結されており、変位センサ8は、水タンク2の液面を検出し、液面高さから孔壁の変位が求められる。変位検出手段としては、変位センサ8に限られず、水タンクに設けた目盛りによって目視で計測するようにしてもよい。

【0012】ゴムゾンデ1は縦方向には固定で横方向にのみ膨張収縮するようになっており、ボーリング孔100の孔壁に密着するゴムチューブ等の中空の可撓性部材を備えている。圧力供給部4は、たとえば、高圧窒素ガス等の圧力源と、圧力源から供給されるガス圧を一定に保つレギュレータバルブ等から構成される。圧力源としては、高圧ガスではなくコンプレッサ等を用いることも

できる。

【0013】圧力制御弁5にはサーボ弁が用いられ、図1（B）に示すように、指令信号に応じて圧力を制御可能となっており、図2（A）に示すように、所定の周期でもって圧力が変動するようにプログラムされたコンピュータ7からの制御信号に基づいて圧力制御弁5のバルブ駆動部51を制御し、たとえばバルブの開度を変えることにより出力圧を周期的に変化させる。出力圧は圧力センサ52によって検出され、サーボアンプ53にフィードバックされ、指令信号に正確に追従するように制御される。

【0014】次に、上記試験装置による試験手順を説明する。原理的には、予想される降伏荷重または非液状化限界荷重（Pl）を何段階かに分けて載荷し、各荷重ごとプラスαの繰り返し荷重を繰返しかけて、地盤の変位量を測定する。以下、同様に載荷荷重を上げていき地盤が破壊されるまで試験を続行し、繰り返し荷重の大きさと変位量の関係から、動的特性を求める。図示例では、繰り返し荷重は正弦波であるが、波形については限定されるものではないし、衝撃な荷重を加えてもよい。繰り返し荷重の振動または繰返し回数としては、地震の振動または繰返し回数などを考慮して設定されるが、0．5～5［Hz］程度、好ましくは1～2［Hz］程度に設定することが好適である。この実施の形態2では、動的特性の指標として、降伏荷重Pyと破壊荷重Plそして変形係数を求める。

【0015】以下、具体的な試験手順を説明する。

①試験の設定

ゴムゾンデ1をボーリング孔100の試験対象土層まで降ろし、ゴムゾンデ1が孔壁に密着して変位が安定するまでゴムゾンデ1に静的な圧力（乱れの要素の無い圧力）を加えて膨らませ、変位が安定した時点の圧力を初期圧P0とする。予想される破壊荷重または非液状化限界荷重Plを設定し、初期圧P0との差圧をN段階に分け、荷重増分（ΔP）＝（Pl－P0）／Nを決め、各荷重段階で、繰返し荷重をn回、または一定時間Tn加えて試験する。予想される破壊荷重または非液状化限界荷重は、試験目的に応じて、高く設定してもよいし、低く設定してもよく、必要に応じて任意に設定される。たとえば、重要な地盤の試験の場合には高く見積もって試験を行う。非液状化限界荷重とはこれ以上荷重をかけても液状化しないであろうと予想される荷重の意味であり、地盤に応じて判断される。繰り返し荷重を載荷する回数，時間については種々設定可能であり、たとえば、地震の際の揺れている時間などを考慮して決められる。この例では荷重段階は10段階とし、繰り返し荷重を20回または20秒間を限度として試験した。地震の際の揺れは20秒程度であり、この程度かければ地震の際の地盤の特性が把握できるし、それ以上となると試験時間が長くなりすぎるからである。

【0016】②第1荷重段階

まず、繰り返し荷重（P0～P0＋α）段階を20回または20秒間載荷し、それぞれの変位量を読み取る。繰り返し荷重のαはΔPを越えない範囲とすることが好適で、αをほぼΔPと等しくすることが好ましい。

【0017】③第k荷重段階

以下、段階的に荷重を大きくして、試験を繰り返す。たとえば、k番目の荷重段階の場合には、荷重（Pk）を（P0＋（k－1）＊ΔP）まで大きくし、繰り返し荷重（Pk＋α）を20回または20秒間載荷して変位を測定する。このようにして測定したデータを、図2（B）にモデル的に示すようにグラフ化する。このグラフは各荷重段階での最終変位r1，r2，r3・・・を記入している。本実施の形態の場合、圧力センサによって読み取られたデータはコンピュータに読み込まれ、自動的にデータが処理され、降伏荷重Pyと破壊荷重Plおよび変形係数を求める。変形係数とはグラフで見れば、降伏荷重Pyに至るまでの直線部分の勾配である。

【0018】繰返し回数nが増えるに従って変位量rが増大し、これらの結果を系統立てて解析することで地盤の強度，動的変形特性を知ることができる。すなわち、種々の土質の試験結果を比較しながら、液状化を起こし易いかどうか等の判定が可能となる。砂質地盤の場合には急激に破壊され、荷重と変位の関係が急激に極限状態に陥る傾向がでると想定される。この急激な変化の度合いを見ることで液状化の度合いの判断も可能である。また、粘土質地盤の場合、極限状態に陥る過程もややゆっくりと出ることが想定される。この傾向を見ることで動的特性の度合いの判定も可能である。また、動的な繰り返し荷重を受けることで急激に強度の低下する性質の高い土ほど早く極限状態が現れ、強度低下率の度合いの判定も可能となる。

【0019】④　測定中での注目点

変位の変化に常に注意を払い、比例的な変化から変化が急になりだした時点を記録しておく。変位が急激に変化した時点を降伏状態として測定を終了するか、破壊荷重を確認して終了する。ゴムゾンデ1の圧力をP0以下に戻してから、ゴムゾンデ1を引き上げる。引き上げる際の抵抗に注目する。引き抜くのが大変な場合は液状化して孔が崩れている可能性がある。なお、上記実施の形態では、荷重と変位の関係をグラフ化しているが、図7（A）乃至（D）に示すように、各荷重段階の繰返し回数nと変位rの関係をグラフ化して振動または繰返し回数に対する特性を評価することも可能である。このグラフは、各荷重段階での繰り返し荷重に対する変位のピーク値（繰り返し荷重の各ピーク値に対応する）をプロットしたものである。繰り返し荷重が加わる毎に徐々に土層に歪みが蓄積されて変位が大きくなっていく。図7（A）乃至（C）の第1段，第2段，第3段の変位が増大する度合い（グラフの勾配）は等しく、降伏段階で変

位の勾配が大きくなり（図７（Ｄ））、土層が破壊に至る段階では、図７（Ｅ）に示すように、変位が急激に変化する。このようなデータをとることにより、各土層の繰り返し荷重に対する強度，動的変形特性を知ることができる。また、荷重を加える時間と変位の関係をグラフ化してその特性を評価してもよく、必要に応じて種々の特性を求めることが可能である。

【００２０】上記実施の形態１では、繰り返し荷重は孔壁に対して孔軸と直交する方向（水平方向）に載荷する圧縮荷重としたが、繰り返し荷重としては、孔壁に対して孔軸を中心とする回転方向に載荷するねじりせん断荷重とすることもできるし、孔壁に対して孔軸と平行方向に載荷するせん断荷重とすることもできる。たとえば、ねじりせん断振動試験を行う場合には、図１に示すように、基本的には上記実施の形態の測定用セル１を孔壁に密接させた状態で測定用セル１に孔軸回りに繰り返し荷重を加えるトルク発生装置９と、このトルク発生装置９によって加えた繰り返し荷重による孔壁の回転変位を検出する変位検出手段としての変位検出部１０と、を設ければよい。

【００２１】また、せん断振動試験を行う場合には、測定用セル１を孔壁に密接させた状態で測定用セル１に孔軸と平行方向に繰り返し荷重を加えるせん断荷重を加えるせん断荷重発生装置１１とせん断荷重による孔壁の軸方向変位を検出する変位検出手段としての変位検出部１２と、を備えた構成とすればよい。上記トルク発生装置９およびせん断荷重発生装置１１としては種々の構成が可能であるが、油圧あるいは空気圧等の流体圧を用いた装置が好適であり、油圧や空気圧を利用したアクチュエータと、サーボ弁などの油圧あるいは空気圧制御弁によって構成することができる。

【００２２】実施の形態２

次に本発明の実施の形態２について説明する。図３は本発明のボーリング孔を利用した原位置における地盤の液状化および動的特性試験方法が適用される試験装置の概略構成が示されている。上記実施の形態１では、ゴムゾンデによって一つの土層に繰り返し試験を行うようにしたが、この実施の形態２では、上下段の土層Ｊ１，Ｊ３に交互に繰り返し荷重を掛けて不動の中間土層Ｊ２の上下にせん断力を作用させるようにしたものである。すなわち、ボーリング孔１００内に挿入され孔軸方向に第１，第２，第３室１１１，１１２，１１３の３室に区分され圧力媒体としての水等の液体が満たされた複数の加圧部を備えた測定用セルとしてのゴムゾンデ１１０と、このゴムゾンデ１１０の加圧部を構成する第１室１１１と第３室１１３の水に交互に圧力を加えて交互に膨張，収縮させる第１，第３圧力調整部１２１，１２３と、第２室１１２内の水圧を調整する圧力調整部１２２と、を備えている。

【００２３】ゴムゾンデ１１０は、図４および図５に示すように、円筒形状の本体部１１４と、本体部１１４の外周に被着される可撓性部材である筒状のゴム部材１１５と、から構成されている。ゴム部材１１５は、第１，第２，第３室１１１，１１２，１１３の全長を覆い、第１室１１１と第２室１１２の境界部、第２室１１２と第３室１１３の境界部を締め付け部材１１６で締め付けて３室に区分してもよいし、第１，第２，第３室１１１，１１２，１１３の各室毎に取り付けてもよいし、種々の構造を選択することができる。以下、第１室１１１に対応するゴム部材を１１５Ａ，第２室１１２に対応するゴム部材を１１５Ｂ、第３室１１３に対応するゴム部材を１１５Ｃとする。これらゴム部材１１５Ａ，１１５Ｂ，１１５Ｃと第１室，第２室１１２，第３室１１１，１１３により加圧部が構成される。中間の第２室１１２（ゴム部材１１５Ｂ）の長さＬ２は、ほぼゴムゾンデ１１０の直径Ｄ程度に設定しておくことが好ましい。第２室１１２（ゴム部材１１５Ｂ）の長さＬ２があまり狭いと早い段階から破壊が始まるし、あまり広いと影響が出にくいからである。また、第１，第３室１１１，１１３（ゴム部材１１５Ａ，１１５Ｃ）の長さＬ１，Ｌ３は、Ｄの１．５から２．５倍程度がよく、２倍程度が最適である。また、Ｄは５ｃｍから２０ｃｍ程度に設定することが好ましい。もちろんは、寸法はこの寸法に限定されるわけではない。この程度の大きさにすれば、ゴム部材１１５の第１，第３室の１１１，１１３に対応するゴム部材１１５Ａ，１１５Ｃが球状に膨らみ、中間土層Ｊ２に対し上下から圧縮する方向の力が働く。

【００２４】第１，第３圧力調整部１２１，１２３は、圧力源としての高圧のガスボンベ１２０Ａと、ガスボンベ１２０Ａから供給されるガスを定圧にして一定量貯留するガスタンク１２０Ｂと、ガスタンク１２０Ｂからの圧力で作動する水圧シリンダ１２１Ｃ，１２３Ｃと、を備えている。ガスタンク１２０Ｂと水圧シリンダ１２１Ｃ，１２３Ｃの間には圧力を逃がすバルブ１２１Ｅ，１２３Ｅと、圧力を供給するバルブ１２１Ｄ，１２３Ｄが設けられ、これらのバルブ１２１Ｄ，１２１Ｅ；１２３Ｄ，１２３Ｅを調整することで、ゴムゾンデ１１０の第１，第３室１１１，１１３に繰り返し圧力を加えるようになっている。たとえば、バルブ１２１Ｄ，１２３Ｄを圧力制御弁とし、バルブ１２１Ｅ，１２３Ｅを閉じた状態で、バルブ１２１Ｄ，１２３Ｄによって水圧シリンダ１２１Ｃ，１２３Ｃに供給するガス圧を制御して、水圧シリンダ１２１Ｃ，１２３Ｃを介して第１，第３室１１１，１１３に交互に荷重を加えればよい。図６ではバルブ１２１Ｄ，１２３Ｄを手動バルブのシンボルで記載しているが、電気的に制御される圧力制御弁等、種々のバルブを適用可能である。試験終了後、バルブ１２１Ｅ，１２３Ｅを開いて水圧シリンダ１２１Ｃ，１２３Ｃからガス圧を抜く。この例では圧力媒体としては水であり、ゴム部材１１５Ａ，１１５Ｃは水圧によって膨張，収縮

する。

【0025】第2圧力調整部122は水圧シリンダは設けないで、水3を地上の水タンク122C内に貯留し、水タンク122C内のヘッドスペースにガスボンベ122Aから高圧ガスを供給して水タンク122C内の水を加圧し、圧力制御弁122Dによってこの高圧気体の圧力を制御している。もっとも、第1，第3圧力調整部121，123と同様に水圧シリンダを用いてもよい。水圧シリンダ121Cとゴムゾンデ110の第1室111とは第1通路131により、水タンク120Cと第2室112とは第2通路132により、水圧シリンダ123Cと第3室113とは第3通路133により連通されている。これら第1，第2，第3通路131，132，133はゴムゾンデ110が取り付けられるボーリングロッド140に設けられる。

【0026】また、ゴムゾンデ110の第1室111，第3室113によって圧縮される上段土層J1，下段土層J3の変位を検出する変位検出手段として、水圧シリンダ121C，123Dに、ピストンの変位を検出する変位センサ151，152が設けられている。このピストンの変位からゴムゾンデ110のゴム部材115A，115Cの変位量、すなわち孔壁の変位が測定される。また、ゴムゾンデ110の第2室112によって圧縮される中間土層J2の変位を検出する変位検出手段として、水タンク122C内の水位の変化を変位センサ153が設けられている。この水位の変位量から第2室112のゴム部材115Bの変位量、すなわち孔壁の変位が測定される。さらに、ゴムゾンデ110の下端部には液状化の発生を検証するための間隙水圧計150が設けられている。この間隙水圧計150はセルの側面に設けてもよいが、孔壁に粘土膜があって水圧が測定できない可能性があるので、図3（B）に示すように、下端110C面側に設けることが好適である。また、下端面110Cにはゴムゾンデ110をボーリング孔100内に降ろしていく途中でゾンデ110によって削られて土が付着する場合があるので、下端面の凹部110Dの奥に取付けることが望ましい。

【0027】次に、実施の形態2についての試験方法について、図1を参照して説明する。試験は、上下段の土層J1，J3に繰り返し荷重を交互に加えてその変位をリアルタイムで測定し、その後に中間土層J2の静的載荷試験を行って静的強度を測定する。上下段個々の土層J1，J3への繰り返し荷重の載荷試験自体は、実施の形態1と全く同様であり、予想される降伏荷重または非液状化限界荷重（P1）をN段階に分けて載荷し、各荷重ごとプラスαの繰り返し荷重をn回または所定時間Tnかけて、地盤の変位量rを測定し、各段階の繰り返し荷重載荷毎に中間土層J2の静的強度を測定する。

【0028】以下、具体的な試験手順を説明する。ボーリング孔100を検査すべき地層の深さまで掘削し、ボーリングロッド140によってゴムゾンデ110をボーリング孔100内の所定深さ位置まで挿入し、以下の手順で試験を行う。

①試験の設定

ゴムゾンデ110の第2室112に圧力を供給して、中間土層J2に静的な圧縮荷重を載荷し、中間土層J2の初期強度を測定する。具体的には静的な状態での「荷重P〜変位r曲線」を求める。この時点で、ゴムゾンデ1が孔壁に密着して変位が安定する初期圧P0が求めらる。予想される破壊荷重または非液状化限界荷重をP1とし、初期圧P0との差圧をN段階に分け、荷重増分（ΔP）＝（P1−P0）／Nを決め、ゴムゾンデ110の第1室111，第3室113に各荷重段階で繰返し荷重をn回、または一定時間Tn交互に加えて試験する。繰り返し試験の前に、ゴムゾンデ110の第1室111，第3室113に初期圧P0を加えておく。

【0029】②第1荷重段階

第1荷重段階は、第1室111および第3室113に、P0〜P0＋αの大きさの繰り返し荷重をn回交互に載荷し、第1室111および第3室113に対応する上段土層J1および下段土層J3の変位を測定し、実施の形態1と同様に荷重と変位の関係をリアルタイムで監視しデータをコンピュータに蓄積し、グラフ化する。この場合も、荷重段階は10段階とし、繰り返し荷重を20回または20秒間を限度とする。この場合の載荷荷重は、図3（E）に示すような立ち上がりが急激な衝撃荷重とする。衝撃荷重は急激に立ち上がった後一定時間t0荷重を維持して確実に土層を圧縮し、その後荷重が低下する。第1室111と第3室113の一方に荷重が加わる時には他方には荷重が加わらないように、交互に荷重が加えられる。荷重の低下開始時点は、他方の室への荷重の立ち上がり前となっているが、点線で記載したように他方の室への荷重立ち上がり時点と同時としてもよい。上段土層J1の上下両端部および下段土層J3の上下両端部には圧縮とともに剪断力が作用し、特に中間土層J2については上下の土層J1，J3が交互に圧縮されることから揺れながら剪断力が作用することになり（図3（A）〜（C）中の×印）、地震の際と同様のダメージが土層に加わる。ゴムゾンデ110の形状が、第2室112の長さL2がゴムゾンデ110の直径D程度となっているので、破壊に至る現象を適切に捉えることができ、第1，第3室111，113の長さL1，L3がDの2倍程度となっているので、ゴム部材115A，115Cが球状に膨らむので変位が大きくなり、しかも圧縮力の分力が直接中間土層J2に対して作用し、土層に対する荷重の影響を高めることができる。

③繰り返し荷重試験後、再び第2室J2に圧力を供給して中間土層J2に静的な圧縮荷重を載荷し、中間土層J2の強度測定を行い、初期強度からどの程度低下したかのデータを得る。このサイクルを1サイクルとし、載荷

荷重をΔP毎、順次大きくして繰り返し試験を行い、基本的には土層の破壊が生じるまで行う。図8には、中間土層J２の静的強度試験の試験結果モデルを示している。図８（Ａ）は、縦軸を中間土層Ｊ２に加える静的荷重Ｐ、横軸を時間としたグラフ、図８（Ｂ）は、縦軸を荷重を加えられた中間土層Ｊ２の変位ｒ、横軸を時間としたグラフである。また、図８（Ｃ）乃至（Ｆ）は、図８（Ａ），（Ｂ）に示す、各段階での中間土層Ｊ２の荷重と変位の関係を示すグラフである。図８（Ａ），（Ｂ）に示すように、まず、繰り返し試験を行う前の中間土層の初期強度を測定する。ゴムゾンデ１１０の第２室１１２のゴム部材１１５Ｂがボーリング孔１００の孔壁に密着するまでは圧力が上がらず変位だけが大きくなり、孔壁に密着すると圧力が急激に増大し、逆に変位の変化は小さくなって初期圧力Ｐ０に達し、荷重に対する変位の変化が安定する。この安定した領域で荷重をＰ０＋δまで増大させて変位を検出し、図８（Ｃ）に示すように、初期段階の中間土層の荷重－変位曲線（横軸を荷重、縦軸を変位）を作成する。この荷重－変位曲線の勾配を変形係数とする。測定後、荷重をＰ０（０）に戻す。荷重をＰ０に戻しても、中間土層Ｊ２に永久歪みが残るので、変位は元には戻らない。圧力増分δの大きさは、上下段土層Ｊ１，Ｊ３に加える繰り返し荷重の振幅の数分の１程度とし、荷重と変位の関係が分かる程度であればよい。次に、上下段土層Ｊ１，Ｊ３に対して１回目の繰り返し試験を行なった後に、中間土層Ｊ１の静的な強度試験を行う。圧力をかけても荷重Ｐ０はゴムゾンデのゴム部材１１５Ｂが初期圧力測定時の永久歪みの分だけ膨らむまで荷重が上昇せず変位だけが大きくなり、永久歪みを吸収した時点で圧力が急激に増大し、逆に変位の変化は小さくなって試験開始荷重Ｐ０（１）に達し、この安定した領域で荷重をＰ０（１）＋δまで増大させて変位を検出し、１回目の繰り返し試験後の中間土層の荷重－変位曲線を作成し（図８（Ｄ）参照）、グラフの勾配を変形係数とする。測定後、荷重を試験開始荷重Ｐ０（１）まで戻す。荷重をＰ０（１）に戻しても、中間土層Ｊ２に永久歪みが残るので変位は試験開始時点の変位まで戻らない。以下、同様に上下段土層Ｊ１，Ｊ３の繰り返し試験後に、中間土層Ｊ２の静的強度試験を行う。弾性領域では、荷重－変位曲線から得られる変形係数はほぼ等しい。何回目かの繰り返し試験後（ｋ回目）、中間土層Ｊ２が降伏状態となった場合には、まず、試験開始荷重（Ｐ０（ｋ））に達した後、（Ｐ０（ｋ）＋δ）まで荷重が増大するのに時間がかかり、なかなか荷重が上がらないで変位が大きく増大していく。この時の荷重－変位曲線は勾配が急になる（図８（Ｅ）参照）。さらに、中間土層Ｊ２が破壊した場合（ｍ回目、図では降伏段階の次段として記載している）、荷重は破壊荷重Ｐ１をピークとして低下していき、地下水圧などのある圧力まで降下した時点で一定となる。変位は破壊荷重近くから急激に増大し（図８（Ｂ））、荷重－変位曲線は、図８（Ｆ）に示すように、圧力が低下してもさらに変位が増大するグラフ形状となる。

【００３０】上段および下段土層Ｊ１，Ｊ３の繰り返し荷重に対する変位のデータ、および中間土層Ｊ２の静的荷重に対する変位のデータを合わせて、繰り返し荷重に対する動的な変形特性を判断し、降伏点や破壊点等の強度を求める。また、土層の液状化は剪断力が上下から作用する中間土層Ｊ２で生じるものと想定され、液状化が生じると、図８に示す測定データの変位が急激に大きくなるので液状化が生じたことが分かる。また、間隙水圧計１５０による間隙水圧が一定となることによっても液状化を検証でき、液状化が生じたかどうかを２重に検証することができる。このように、本実施の形態２によれば、実施の形態１のようなねじりせん断試験や軸方向せん断試を行うことなく、上下段の土層への単純な圧縮荷重の交互載荷によってせん断力を中間土層に加えることができ、簡易な構成で、確実に、短時間に、かつ低コストで、精度の高い土層の動的特性試験を行うことができる。

【００３１】上記実施の形態２では、ゴムゾンデに静的な荷重を載荷する不動部を設けたが、不動部を設けないで上下の繰り返し荷重載荷部のみによって構成し、上下段土層の変形のみ注目してもよい。上下段土層の境界部には剪断力が作用しており、液状化が発生すると上下段土層に波及するからである。また、繰り返し荷重を上下２段としたが、上下３段以上としてもよく、その場合には各繰り返し荷重載荷部の中間に不動部を設ければよい。

【００３２】繰り返し荷重としては、孔軸と直交する方向に載荷される圧縮荷重と、孔軸を中心とする回転方向に載荷されるねじりせん断荷重と、孔軸と平行方向に載荷されるせん断荷重の３つの荷重のうち、それぞれ単独に載荷することもできるし、少なくとも２種類の荷重を組み合わせた組み合わせて載荷することもできる。

【００３３】なお、上記実施の形態１，２では、ボーリング孔１００を垂直に掘った場合を例にとって説明したが、たとえば水平に掘る場合や、斜めに掘った場合についても適用可能である。また、測定用セルとしては、ゴムゾンデ１１０，１の代わりに、金属製の載荷板を油圧等によって加圧するピストンジャッキ等を用いてもよく、土層に応じて適切な測定用セルが選択される。

【００３４】

【発明の効果】以上説明したように、本発明によれば、地下のサンプルを取り出すことなく、原位置で試験できるので、自然状態での土層の繰り返し荷重に対する強度および変形特性を求めることができる。特に、非常にゆるい砂層あるいは礫などの混入でサンプリングが不可能な土層、砂礫層など粒径の大きい土層または風化岩、軟岩などでも測定が可能であり、利用範囲が広がる。ま

た、従来のサンプル試験に対して短時間で試験が可能なために、経済的である。

【００３５】特に、ボールリング孔の孔壁の孔軸方向の複数の領域に交互に繰り返し圧縮荷重を載荷することにより、載荷領域の境界部に実際の地震の横揺れに似た形の繰り返しせん断力を加わえることができ、繰り返し圧縮荷重に対する特性と同時に、せん断力に対する特性についても試験することができる。液状化はせん断力によって生じやすくなるので、液状化の判定に有効である。境界部が崩れると圧縮荷重載荷領域にも液状化が拡がり、変位が大きく変化するため液状化が判定できる。また、ボールリング孔の孔壁の一領域に繰り返し荷重をかける場合でも、データの解析手法により、種々の地盤の特性を検討できる。この場合には、孔軸と直交する方向に載荷される圧縮荷重と、孔軸を中心とする回転方向に載荷されるねじりせん断荷重と、孔軸と平行方向に載荷されるせん断荷重の３つの荷重のうちの一つ、または少なくとも２種類の荷重を組み合わせた組み合わせ荷重を載荷して試験することにより、ねじられながら圧縮やせん断荷重が作用するような実際に即した繰り返し荷重に対する試験を行うことができる。

【図面の簡単な説明】

【図１】　図1（Ａ）は本発明の実施の形態１に係るボーリング孔を利用した原位置での地盤の液状化および動的特性試験装置の概略構成を示す図、図１（Ｂ）は圧力制御弁の制御構成を示す図である。

【図２】　図2（Ａ）は図１の圧力制御弁による出力例を示す図、同図（Ｂ）は図１の試験結果のモデルを示すグラフである。

【図３】　図3（Ａ）乃至（Ｅ）は本発明の実施の形態２に係るボーリング孔を利用した原位置での地盤の液状化および動的特性試験方法を示す説明図である。

【図４】　図４は図３のゴムゾンデの機能説明図である。

【図５】　図5は図４のゴムゾンデの概略構成図である。

【図６】　図６は本発明の実施の形態２に係るボーリング孔を利用した原位置での地盤の液状化および動的特性試験装置の構成例を示す説明図である。

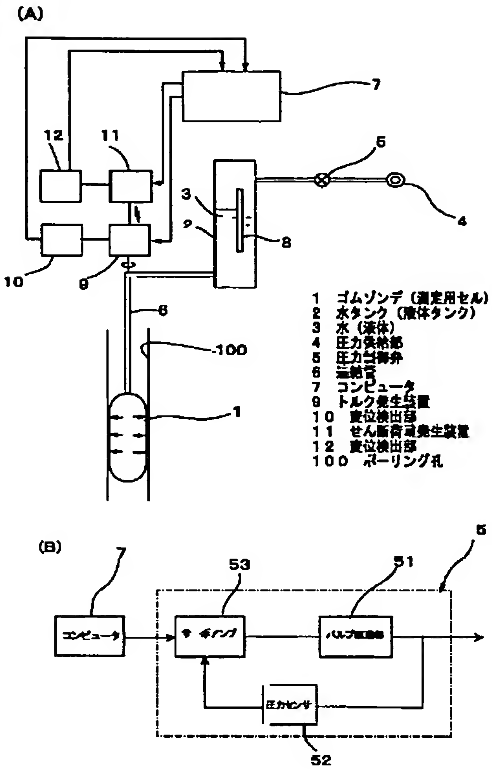
【図７】　図7は図１の試験結果モデルの他のグラフである。

【図８】　図8（Ａ）乃至（Ｆ）は中間土層の静的強度試験の試験結果モデルを示すグラフである。

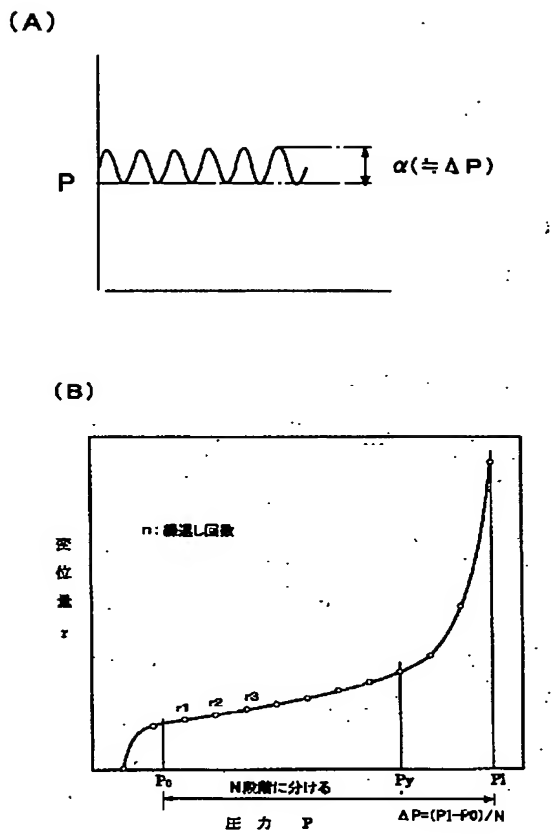
【符号の説明】

１　ゴムゾンデ（測定用セル）、２　水タンク（液体タンク）、３　水（液体）、
４　圧力供給部、５　圧力制御弁、６　連結管、
７　コンピュータ、
９トルク発生装置、１０　変位検出部、
１１　せん断荷重発生装置、１２　変位検出部
１００　ボーリング孔
１１０　ゴムゾンデ
１１１，１１２，１１３　第1，第2，第3室
１２１，１２２，１２３　第1，第2，第3圧力調整部
１１４　本体部、１１５　ゴム部材、１１６　締め付け部材
１２０Ａ　ガスボンベ、１２０Ｂ　ガスタンク
１２１Ｃ，１２３Ｃ　水圧シリンダ
１２１Ｄ，１２３Ｄ　バルブ
１２１Ｅ，１２３Ｅ　バルブ
１２２Ｃ　水タンク１２２Ｃ、１２２Ｄ　圧力制御弁
Ｊ１　上段土層、Ｊ２　中間土層、Ｊ３　下段土層
１５０　間隙水圧計

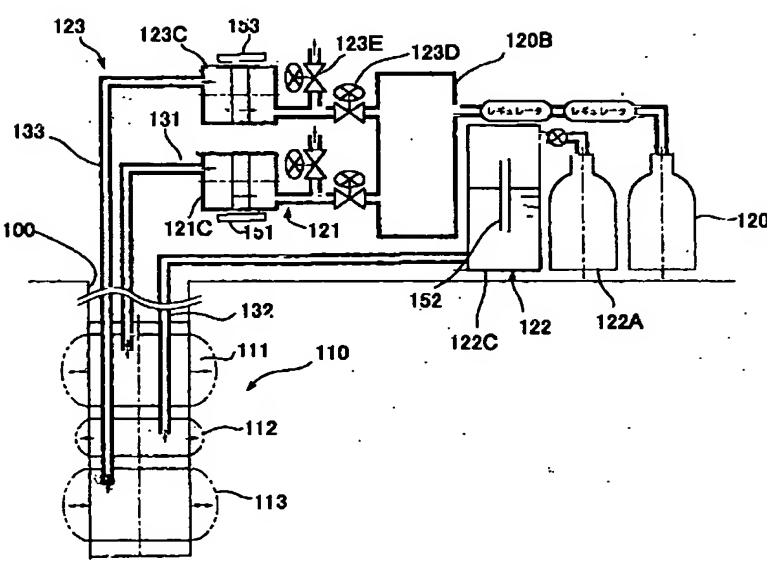
【図1】


(A)
7
12
11
5
3
4
9
8
10
9
6
100
1
1　ゴムゾンデ（測定用セル）
2　水タンク（液体タンク）
3　水（液体）
4　圧力供給部
5　圧力制御弁
6　連結管
7　コンピュータ
9　トルク発生装置
10　変位検出部
11　せん断荷重発生装置
12　変位検出部
100　ボーリング孔
(B)
7
53
51
5
コンピュータ
圧力センサ
52

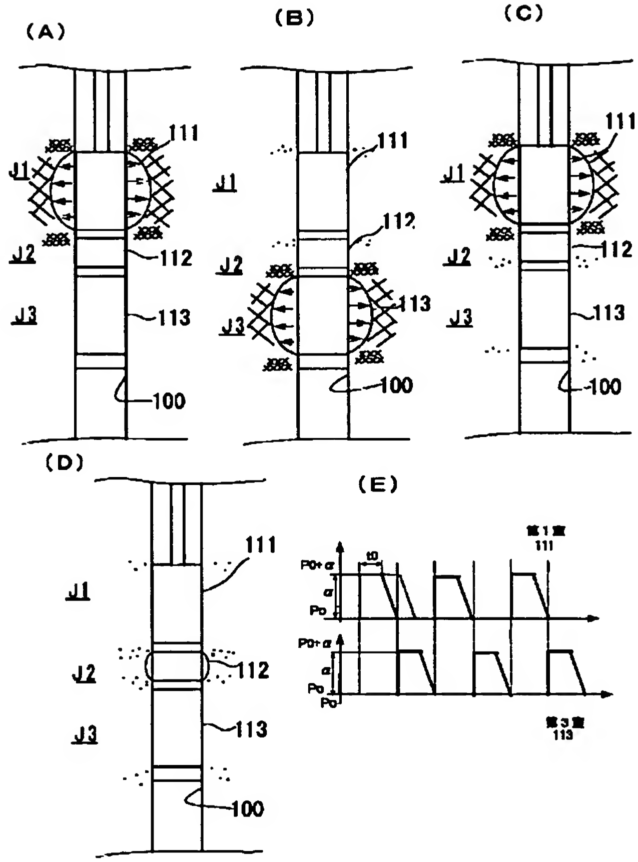
【図2】


(A)
P
α(≒ΔP)
(B)
n：繰返し回数
変位量 r
r1
r2
r3
P0
Py
P1
N段階に分ける
圧力 P
ΔP=(P1−P0)/N

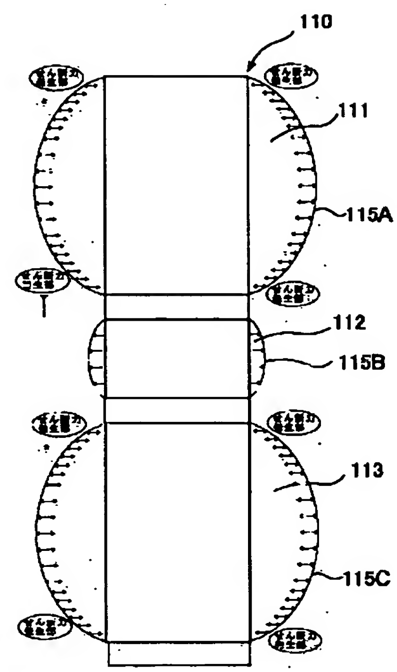
【図6】


123
123C
153
123E
123D
120B
レギュレータ
レギュレータ
133
131
100
121C
151
121
120A
152
122
122C
122A
132
111
110
112
113

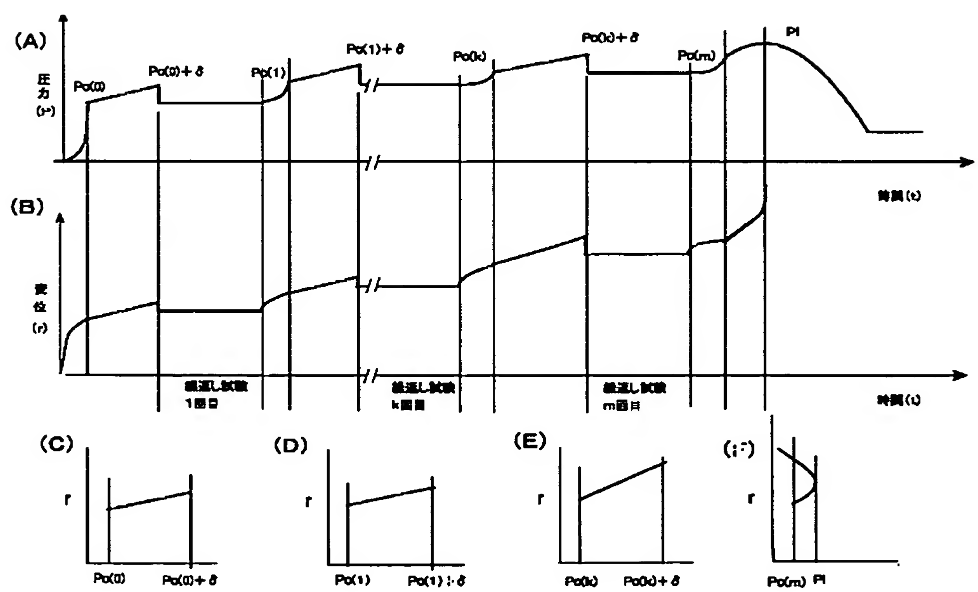
【図3】


(A)
(B)
(C)
(D)
(E)
J1
J2
J3
111
112
113
100
P0+α
α
Po
t0
第1室
111
第3室
113

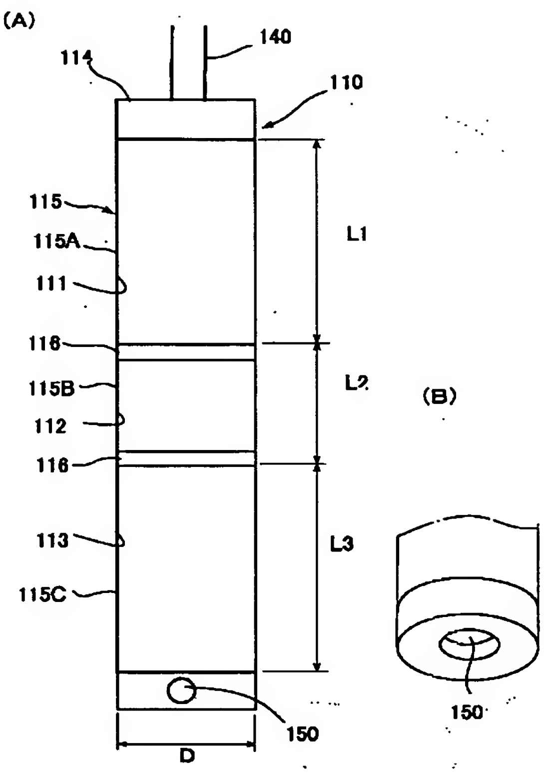
【図4】


110
111
115A
112
115B
113
115C

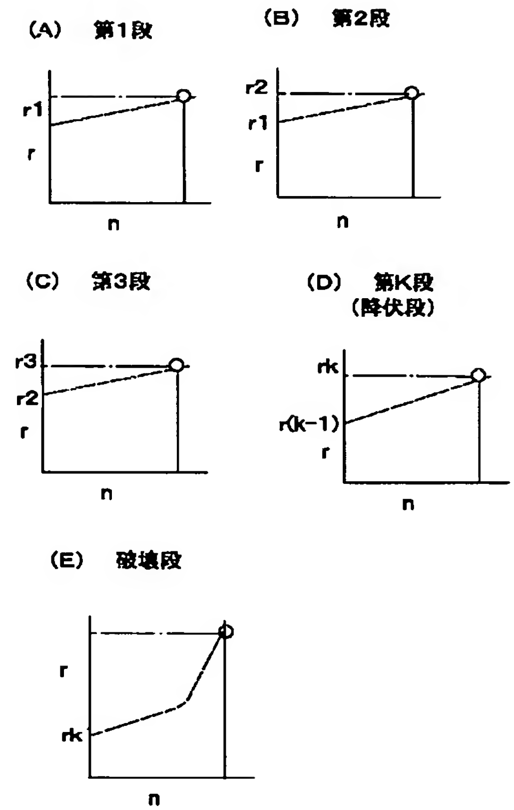
【図8】


(A)
(B)
(C)
(D)
(E)
圧力
変位
(r)
時間(t)
Po(0)
Po(0)+δ
Po(1)
Po(1)+δ
Po(k)
Po(k)+δ
Po(m)
Pl
繰返し試験 1回目
繰返し試験 k回目
繰返し試験 m回目
r

【図5】


(A)
114
140
110
115
115A
111
116
115B
112
116
113
115C
L1
L2
L3
150
D
(B)
150

【図7】


(A) 第1段
r1
r
n
(B) 第2段
r2
r1
r
n
(C) 第3段
r3
r2
r
n
(D) 第K段
(降伏段)
rk
r(k-1)
r
n
(E) 破壊段
r
rk
n

CLAIMS

[Claim(s)]
[Claim 1] Liquefaction and the dynamic trait test method of the foundation in the original location using the bar hole characterized by loading with a repeated load the test objective soil layer of the porous wall of the bar hole established in the foundation, measuring the variation rate of a porous wall, and searching for the dynamic trait of the foundation.
[Claim 2] The liquefaction and the dynamic trait test method of the foundation in the original location using the bar hole according to claim 1 characterized by repeating by turns the shearing force of the direction which intersects a hole axis to the middle soil layer of the loading field of a load, and making it act on it by loading two or more fields of the direction of a hole axis of the porous wall of a bar hole with a repeated load by turns.
[Claim 3] The liquefaction and the dynamic trait test method of the foundation in the original location using the bar hole according to claim 2 which loads with a static load the middle soil layer which performed the repeat trial, and measures reinforcement.
[Claim 4] Liquefaction and the dynamic trait test method of the foundation in the original location which loaded one field of the porous wall of a bar hole with vibration or a repeated load by turns, and used the bar hole according to claim 1 which gets to know the dynamic trait of the foundation from the relation between the magnitude of a repeat load, vibration or a repeat count, and a variation rate.
[Claim 5] A repeated load is liquefaction and the dynamic trait test method of 1 of three loads, the compressive load by which loading is carried out in the direction which intersects perpendicularly with a hole axis, the torsion shear load by which loading is carried out to the hand of cut centering on a hole axis, and the shear load by which loading is carried out to a hole axis and a parallel direction, or the foundation in the original location which combined and used the bar hole according to claim 1 or 4 for which at least two kinds of loads were combined, and which is a load.
[Claim 6] Liquefaction and the dynamic trait testing device of the foundation in the original location using the bar hole characterized by having the cel for measurement which presses a porous wall with the pressure of a pressure medium while being inserted into the bar hole established in the foundation, the pressure regulation means which can fluctuate periodically the pressure of the pressure medium in this cel for measurement, and the displacement detection means for detecting the variation rate of said porous wall.
[Claim 7] The cel for measurement is liquefaction and the dynamic trait testing device of the foundation in the original location using the bar hole according to claim 6 which applies a pressure to the pressure medium of two or more interior of a room [it is classified into two or more ** which press a porous wall along the direction of a hole axis of a bar hole, and / **** / pressure regulation] repeatedly by turns.
[Claim 8] A pressure regulation means is liquefaction and the dynamic trait testing device of the foundation in the original location using the bar hole according to claim 7 which separates a middle room, applies a pressure to up-and-down ** repeatedly by turns, and applies a static pressure to a middle room.
[Claim 9] rotation of the porous wall by the repeated load added to the cel for measurement in the condition made the cel for measurement close to a porous wall, with a torque generating means to add a repeated load at the circumference of a hole axis, and this torque generating means -- the variation rate which detects a variation rate -- liquefaction and the dynamic trait testing device of the foundation in the original location using the bar hole according to claim 6 characterized by to have the detection means.
[Claim 10] the shaft orientations of a shear load generating means to add a repeated load to the cel for measurement in the condition of having made the cel for measurement close to a porous wall at a hole axis and a parallel direction, and the porous wall by the shear load -- the variation rate which detects a variation rate -- liquefaction and the dynamic trait testing device of the foundation in the original location using the bar hole according to claim 6 or 9 characterized by having the detection means.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[The technical field to which invention belongs] This invention relates to the liquefaction, dynamic trait (reinforcement, deformation property) test method, and testing device using the bar hole which inspects the property in the original location of the foundation when repeated loads, such as earthquake force, traffic load, and a machine load, act of the foundation.
[0002]
[Description of the Prior Art] The conventional foundation inspection bowls by predetermined Mr. Fukashi, takes down the detection sound as a cel for measurement in a bar hole, blows up a detection sound, loads a porous wall with horizontal load, and detects the static reinforcement and the deformation property of the foundation from the variation rate of the porous wall to a load.
[0003]
[Problem(s) to be Solved by the Invention] However, by the conventional foundation inspection, having detected the static property was not only able to estimate the dynamic trait of the reinforcement or the deformation property of the foundation over repeated loads, such as earthquake force, traffic load, and a machine load. in case of an earthquake, even if the force of joining the foundation is the magnitude which is not destroyed statically, it is gradually -- it is -- it is very important for distortion to become large, and it to be thought rapidly, for that it results in destruction, and to investigate the property of the foundation over a repeated load. It is thought that the force complicated in a horizontal, the upper and lower sides, and the direction of torsion acts in the foundation in case of an earthquake, and although it is very important to get to know the dynamic property of the foundation in the original location at the time of such complicated force acting, the approach of measuring and evaluating in the foundation of a original location is not established conventionally.
[0004] Although there were what judges the property inclination of the whole foundation (refer to JP,7-3760,A), a thing (refer to JP,7-109725,A) which detects liquefaction at the time of the occurrence of an earthquake as the judgment approach of the conventional liquefaction, for example, it was not that to which all examine directly the dynamic trait of the soil layer in the foundation itself.
[0005] As an approach of getting to know the dynamic property over the repeated load of the soil layer itself, the sample of the soil in current and the condition of not bowling and disturbing is extracted, this is carried into a laboratory, and it is asking by carrying out a soil test. However, since the sample which it is not only very difficult to extract in the condition (condition as it is deposited automatically) of not disturbing a sample itself, but it extracted is not in the condition which required the underground pressure, it cannot search for the property in an actual natural condition. Moreover, the soil test in the interior of a room which cannot be sampled in the condition of not disturbing in the case of a soil layer or a weathered rock with large particle size, such as a soil layer, grit, etc. which mix very loose sand stratum or stones etc., a soft rock, etc., either therefore is impossible. As mentioned above, the actual condition can search for directly only the property in the conditions restricted very much in the present condition.
[0006] This invention has the place which it was made in view of the importance of getting to know the dynamic deformation property over the repeated load of the foundation directly, and is made into the purpose in offering the liquefaction, the dynamic trait test method, and the testing device of the foundation in the original location using the bar hole which can acquire the dynamic reinforcement and the deformation property of the foundation in a original location by the simple approach, without needing the sample of the soil in the condition do not disturb.
[0007]
[Means for Solving the Problem] In order to attain the above-mentioned purpose, liquefaction and the dynamic trait test method of the foundation in the original location using the bar hole of this invention are characterized by loading with a repeated load the test objective soil layer of the porous wall of the bar hole established in the foundation, measuring the variation rate of a porous wall, and searching for the dynamic trait of the foundation. It can know also especially about liquefaction of the foundation. Here, a repeated load is semantics including the whole load changed periodically, and a fluctuating load which can be operated also manually and which was carried out slowly is also included from a fluctuating load (vibration) with comparatively high vibration frequency. A dynamic trait is the relation of the load at the time of adding a repeated load, and a variation rate itself, for example, from the relation between the magnitude of a repeated load, a repeat count, and a variation

rate, a deformation property can be grasped, and it can ask for reinforcement and coefficients of strain, such as yield load and a breaking load, or analyzing by systematizing these results can estimate the dynamic property of a soil layer.
[0008] It is effective to load two or more fields of the direction of a hole axis of the porous wall of a ball ring hole with a compressive load especially repeatedly by turns. If it does in this way, it becomes possible to repeat by turns the shearing force of the direction which intersects a shake and a hole axis to the middle soil layer of the loading field of a load, and to make it act on it, and the same force as the time of an earthquake can be applied to a soil layer. The middle soil layer which performed the repeat trial is a part which receives a damage most, if it loads this part with a static compressive load and static reinforcement is measured, has received how many damages or can know that degree. Moreover, one field of the porous wall of a bar hole can be loaded with vibration or a repeated load by turns, and the dynamic trait of the foundation can also be known from the relation between the magnitude of a repeat load, vibration or a repeat count, and a variation rate. A repeated load is a combination load which combined 1 of three loads, the compressive load by which loading is carried out in the direction which intersects perpendicularly with a hole axis, the torsion shear load by which loading is carried out to the hand of cut centering on a hole axis, and the shear load by which loading is carried out to a hole axis and a parallel direction, or at least two kinds of loads.
[0009] Liquefaction and the dynamic trait testing device of the foundation in the original location using the bar hole of this invention are characterized by to have the cel for measurement which presses a porous wall with the pressure of a pressure medium, the pressure-regulation means which can fluctuate periodically the pressure of the pressure medium in this cel for measurement, and the displacement detection means for detecting the variation rate of said porous wall while they are inserted into the bar hole established in the foundation. The cel for measurement has two or more pressurization sections which press a porous wall along the direction of a hole axis of a bar hole, and a pressure regulation means applies a pressure to two or more pressurization sections repeatedly by turns. The cel for measurement is classified into two or more **, and constitutes the pressurization section, and pressure regulation **** applies a pressure to two or more indoor pressure media repeatedly by turns. A pressure regulation means separates a middle room, applies a pressure to up-and-down ** repeatedly by turns, and applies a static pressure to a middle room. rotation of the porous wall by the repeated load added to the cel for measurement in the condition of having made the cel for measurement close to a porous wall, with a torque generating means to add a repeated load at the circumference of a hole axis, and this torque generating means -- the variation rate which detects a variation rate -- it is characterized by having the detection means. the shaft orientations of a shear load generating means to add a repeated load to the cel for measurement in the condition of having made the cel for measurement close to a porous wall at a hole axis and a parallel direction, and the porous wall by the shear load -- the variation rate which detects a variation rate -- it is characterized by having the detection means.
[0010]
[Embodiment of the Invention] This invention is explained based on the gestalt of implementation of illustration below.
Gestalt 1 drawing 1 (A) of operation is liquefaction of the foundation concerning the gestalt 1 of operation of this invention, and the mimetic diagram of a dynamic trait testing device. Liquefaction and the dynamic trait testing device of this foundation The rubber sound 1 as a cel for measurement with which liquids, such as water 3 as a pressure medium, were filled while being inserted into the bar hole 100 established in the foundation, It has the pressure control valve 5 as a pressure regulation means to fluctuate periodically the pressure of the water 3 in the rubber sound 1, and the displacement sensor 8 as a displacement detection means for detecting the variation rate of the porous wall by the pressure from the rubber sound 1.
[0011] Water 3 is stored in the terrestrial water tank 2, a high-pressure gas is supplied to the head space in a water tank 2 from the pressure feed zone 4, the water 3 in a water tank 2 is pressurized, and the pressure control valve 5 is controlling the pressure of this high-pressure gas by the example of illustration. It is good also as not control of a high-pressure gas but a configuration which adjusts water pressure directly depending on the case. Moreover, the water tank 2 and the rubber sound 1 are connected by the interconnecting tube 6, a displacement sensor 8 detects the oil level of a water tank 2, and the variation rate of a porous wall is called for from oil-level height. It is not restricted to a displacement sensor 8, but you may make it measure visually as a displacement detection means with the graduation formed in the water tank.
[0012] The rubber sound 1 is equipped with the flexible member of hollow, such as a rubber tube which carries out expansion contraction only in a longitudinal direction by immobilization at a lengthwise direction and which is stuck to the porous wall of a bar hole 100. The pressure feed zone 4 consists of regulator bulbs which keep constant the gas pressure supplied from pressure sources, such as for example, high-pressure nitrogen gas, and a pressure source. As a pressure source, not high pressure gas but a compressor etc. can also be used.
[0013] As a servo valve is used for a pressure control valve 5, and it is shown in drawing 1 (B), and it has become controllable and a pressure is shown in drawing 2 (A) according to a command signal, an output pressure is periodically changed by controlling the bulb mechanical component 51 of a pressure control valve 5 based on the control signal from the computer 7 programmed to change a pressure as it is also at a predetermined period, for example, changing the opening of a bulb. An output pressure is detected by the pressure sensor 52, is fed back to a servo amplifier 53, and is controlled to follow a command signal correctly.
[0014] Next, the test procedure by the above-mentioned testing device is explained. Several steps are theoretically divided and loaded with the yield load or the non-liquefying critical load (Pl) expected, the

repeated load of Plus alpha is repeated the whole load, and the amount of displacement of the foundation is measured. A trial is continued until it raises the loading load similarly and the foundation is destroyed hereafter, and a dynamic trait is searched for from the magnitude of a repeated load, and the relation of the amount of displacement. In the example of illustration, although a repeated load is a sine wave, it is not limited about a wave and may add an impact load. Although set up in consideration of vibration or a repeat count of an earthquake etc. as vibration or the repeat count of a repeated load, it is suitable 0.5-5 [Hz] extent and to set it as 1-2 [Hz] extent preferably. With the gestalt 2 of this operation, it asks for yield load Py, a breaking load Pl, and a coefficient of strain as an index of a dynamic trait.

[0015] Hereafter, concrete test procedure is explained.

** The experimental setting rubber sound 1 is taken down to the test objective soil layer of a bar hole 100, a static pressure (pressure without the element of turbulence) is applied and swollen to the rubber sound 1 until the rubber sound 1 sticks to a porous wall and a variation rate is stabilized, and let the pressure at the time of a variation rate being stabilized be initial pressure P0. the breaking load or the non-liquefying critical load Pl expected -- setting up -- differential pressure with initial pressure P0 -- N phase -- dividing -- load increment (deltaP) = (Pl-P0) / N -- deciding -- each load phase -- a repeated load -- n times -- or it examines [fixed time amount Tn]. According to the trial purpose, the breaking load or the non-liquefying critical load expected may be set up highly, may be set up low, and is set as arbitration if needed. For example, in the trial of the important foundation, it examines as an estimate highly. Non-liquefying critical load means the load expected not to liquefy even if it applies a load more than this, and it is judged according to the foundation. It is decided in consideration of the time amount to which many things can be set about the count and time amount which load with a repeated load, for example, it is shaking in case of the earthquake. In this example, the load phase was made into ten steps and examined for 20 times or 20 seconds for the repeated load as a limit. The shake in case of an earthquake is about 20 seconds, and it is because test time will become long too much if the property of the foundation in case of an earthquake can be grasped and it becomes more than it if it applies to this extent.

[0016] ** the 1st load **** -- first -- a repeated-load (P0-P0+alpha) phase -- for 20 times or 20 seconds -- loading -- each variation rate -- read an amount. Considering as the range which does not exceed deltaP is suitable for alpha of a repeated load, and it is desirable to make alpha almost equal to deltaP.

[0017] ** Below the k-th load phase, enlarge a load gradually and repeat a trial. the case of the k-th load phase -- a load (Pk) -- up to (P0+(k-1) *deltaP) -- large -- carrying out -- a repeated load (Pk+alpha) -- 20 times -- or it loads for 20 seconds and a variation rate is measured. Thus, as the measured data are shown in drawing 2 (B) in model, it graph-izes. this graph -- the last in each load phase -- variation rates r1, r2, and r3 ... is filled in. In the case of the gestalt of this operation, it is read into a computer, data are processed automatically, and the data read by the pressure sensor ask for yield load Py, a breaking load Pl, and a coefficient of strain. A coefficient of strain will be the inclination of a straight-line part until it results in yield load Py, if it sees in a graph.

[0018] The amount r of displacement increases as repeat-count n increases, and the reinforcement of the foundation and a dynamic deformation property can be known in analyzing these results systematically. That is, the judgment of whether to be easy to cause liquefaction is attained, comparing the test result of various soil texture. In the case of the sandy foundation, it is destroyed rapidly, and it is assumed that a load and the inclination for the relation of a variation rate to lapse into an extreme situation rapidly come out. Decision of the degree of liquefaction is also possible by seeing the degree of this abrupt change. Moreover, in the case of the argillaceous foundation, the process mist which lapses into an extreme situation, and coming out slowly are assumed. The judgment of the degree of a dynamic trait is also possible by seeing this inclination. Moreover, early, soil with the higher property in which reinforcement falls rapidly by receiving a dynamic repeated load appears, and the judgment of the degree of a decreasing rate on the strength of an extreme situation is also attained.

[0019] ** Always pay attention to change of the attention point mutation of a under [measurement], and record the time of change beginning to become sudden from a-like proportionally change. Measurement is ended by making the time of a variation rate changing rapidly into a breakdown condition, or a breaking load is checked and it ends. After returning the pressure of the rubber sound 1 to less than [P0], the rubber sound 1 is pulled up. It takes notice of the resistance at the time of pulling up. When it is serious to draw out, it might liquefy and the hole may have collapsed. In addition, although relation between a load and a variation rate is graph-ized with the gestalt of the above-mentioned implementation, as shown in drawing 7 (A) thru/or (D), it is also possible to graph-ize repeat-count n of each load phase and relation of displacement r, and to evaluate the property over vibration or a repeat count. This graph plots the peak value (it corresponds to each peak value of a repeated load) of the variation rate to the repeated load in each load phase. Whenever a repeated load is added, distortion is gradually accumulated in a soil layer and the variation rate becomes large. The degree (inclination of a graph) to which the variation rate of the 1st step of drawing 7 (A) thru/or (C), the 2nd step, and the 3rd step increases is equal, the inclination of a variation rate becomes large in a breakdown phase (drawing 7 (D)), and in the phase where a soil layer results in destruction, as shown in drawing 7 (E), a variation rate changes rapidly. By taking such data, the reinforcement and the dynamic deformation property over the repeated load of each soil layer can be known. Moreover, it is possible to graph-ize relation of the time amount and the variation rate which add a load, to evaluate the property, and to search for various properties if needed.

[0020] Although the repeated load considered as the compressive load with which it loads in the direction (horizontal) which intersects perpendicularly with a hole axis to a porous wall with the gestalt 1 of the above-mentioned implementation, it can also consider as the torsion shear load with which the hand of cut centering on

a hole axis is loaded to a porous wall as a repeated load, and can also consider as the shear load with which a hole axis and a parallel direction are loaded to a porous wall. for example, rotation of the porous wall by the repeated load added to the cel 1 for measurement with the torque generator 9 which adds a repeated load at the circumference of a hole axis, and this torque generator 9 in the condition of having made the cel 1 for measurement of the gestalt of the above-mentioned implementation close to a porous wall fundamentally as shown in drawing 1 when a torsion shearing oscillation trial was performed -- the variation rate which detects a variation rate -- the variation rate as a detection means -- what is necessary is just to form a detecting element 10

[0021] moreover, the shaft orientations of the porous wall by the shear load generator 11 and shear load which add the shear load which adds a repeated load at a hole axis and a parallel direction to the cel 1 for measurement in the condition of having made the cel 1 for measurement close to a porous wall in performing a shearing oscillation trial -- the variation rate which detects a variation rate -- the variation rate as a detection means -- the configuration equipped with the detecting element 12 -- then, it is good. Although various configurations are possible as the above-mentioned torque generator 9 and a shear load generator 11, the equipment using hydrostatic pressure, such as oil pressure or pneumatic pressure, is suitable, and can constitute by the actuator using oil pressure or pneumatic pressure, and oil pressure or air pressure-limiting valves, such as a servo valve.
[0022] The gestalt 2 of operation of this invention is explained to the secondary gestalt of operation. The outline configuration of the testing device with which the liquefaction and the dynamic trait test method of the foundation in the original location where drawing 3 used the bar hole of this invention are applied is shown. Although it was made to examine to one soil layer by the rubber sound repeatedly, a repeated load is hung on the soil layers J1 and J3 of a vertical stage by turns, and it is made to make shearing force act on the upper and lower sides of the immovable middle soil layer J2 in the gestalt 2 of this operation with the gestalt 1 of the above-mentioned implementation. Namely, the rubber sound 110 as a cel for measurement which was inserted into the bar hole 100 and equipped with the 1st, the 2nd, and two or more pressurization sections with which the 3rd room was classified into three rooms of 111,112,113, and liquids, such as water as a pressure medium, were filled in the direction of a hole axis, It has the 1st and 3rd pressure regulation section 121,123 which constitutes the pressurization section of this rubber sound 110 and which applies the 1st room of the 3rd room of a pressure to the water of 113 by turns with 111, and is expanded and shrunk by turns, and the pressure regulation section 122 which adjusts the water pressure in 2nd room 112.
[0023] the tubed rubber member 115 which is a flexible member put on the periphery of the cylindrical shape-like body section 114 and the body section 114 as the rubber sound 110 is shown in drawing 4 and drawing 5 -- since -- it is constituted. the rubber member 115 -- the 1st, the 2nd, and the 3rd -- the overall length of room 111,112,113 -- covering -- the 1st -- room 111 and the 2nd -- the boundary section of room 112, and the 2nd -- room 112 and the 3rd -- the boundary section of room 113 -- binding tight -- a member 116 -- binding tight -- three rooms -- you may classify -- the 1st and the 2nd -- the 3rd room may be attached every ** of 111,112,113 and various structures can be chosen. Hereafter, 115A and the rubber member corresponding to 112 the 2nd room are set to 115B, and the 3rd room of the 1st room of the rubber member corresponding to 113 is set to 115C for the rubber member corresponding to 111. these rubber members 115A, 115B, and 115C, the 1st room, and the 2nd -- room 112 -- the 3rd room of the pressurization section is constituted by 111,113. The middle thing of the die length L2 of 112 (rubber member 115B) mostly set as the diameter D grade of the rubber sound 110 is desirable the 2nd room. It is because it will be hard to come out of effect if not much large [if the die length L2 of 112 (rubber member 115B) is not much narrow the 2nd room, destruction will start in an early stage, and]. moreover, the 1st -- the 3rd room, the die length L1 and L3 of 111,113 (rubber members 115A and 115C) has about 1.5 to 2.5 of D good times, and its about 2 times are the optimal. Moreover, as for D, it is desirable to set it as about 20cm from 5cm. Of course, ** and a dimension are not necessarily limited to this dimension. If it is made magnitude of this level, the 1st of the rubber member 115 and the rubber members 115A and 115C corresponding to 111,113 of the 3rd room will swell spherically, and the force of the direction compressed from the upper and lower sides to the middle soil layer J2 will work.
[0024] The 1st and 3rd pressure regulation section 121,123 made constant pressure the gas supplied from high-pressure chemical cylinder 120A as a pressure source, and chemical cylinder 120A, and is equipped with gas holder 120B which carries out a constant-rate reservoir, and the hydraulic cylinders 121C and 123C which operate by the pressure from gas holder 120B. gas holder 120B, the bulbs 121E and 123E which miss a pressure among hydraulic cylinders 121C and 123C, and the bulbs 121D and 123D which supply a pressure being formed, and adjusting such bulb 121D, 121E;123D, and 123E -- the 1st of the rubber sound 110 -- the 3rd room of a pressure is repeatedly applied to 111,113. for example, the gas pressure supplied to hydraulic cylinders 121C and 123C by Bulbs 121D and 123D where it used Bulbs 121D and 123D as the pressure control valve and Bulbs 121E and 123E are closed -- controlling -- hydraulic cylinders 121C and 123C -- minding -- the 1st -- what is necessary is just to add the 3rd room of a load to 111,113 by turns Although the symbol of a hand valve has indicated Bulbs 121D and 123D in drawing 6 , various bulbs, such as a pressure control valve controlled electrically, are applicable. After test termination, Bulbs 121E and 123E are opened and gas pressure is extracted from hydraulic cylinders 121C and 123C. In this example, as a pressure medium, it is water, and with water pressure, the rubber members 115A and 115C expand, and are contracted.
[0025] The 2nd pressure regulation section 122 stores water 3 in terrestrial water tank 122C, supplies high pressure gas to the head space in water tank 122C from chemical cylinder 122A, pressurizes the water in water tank 122C, and is controlling the pressure of this high-pressure gas by pressure-control-valve 122D without

preparing a hydraulic cylinder. But a hydraulic cylinder may be used like the 1st and 3rd pressure regulation section 121,123. the 1st of hydraulic cylinder 121C and the rubber sound 110 -- room 111 -- the 1st path 131 -- 112 is opened for free passage by the 2nd path 132 and 113 [room / 2nd / room / 3rd] is opened [C / water tank 120] for free passage by the 3rd path 133 with hydraulic cylinder 123C. These 1st, 2nd, and 3rd paths 131,132,133 are established in the drill rod 140 in which the rubber sound 110 is attached.

[0026] Moreover, the displacement sensor 151,152 which detects the variation rate of a piston to hydraulic cylinders 121C and 123D is formed as a displacement detection means of the rubber sound 110 to detect the 1st room of the variation rate of 111, the upper case soil layer J1 compressed by 113 [room / 3rd], and the lower-berth soil layer J3. The amount of displacement of the rubber members 115A and 115C of the rubber sound 110, i.e., the variation rate of a porous wall, is measured from the variation rate of this piston. Moreover, change of the water level in water tank 122C is prepared in the displacement sensor 153 as a displacement detection means to detect the variation rate of the middle soil layer J2 of the rubber sound 110 compressed by 112 [room / 2nd]. The 2nd room of the amount of displacement of rubber member 115B of 112, i.e., the variation rate of a porous wall, are measured from the amount of displacement of this water level. Furthermore, the piezometer 150 for verifying generating of liquefaction is formed in the lower limit section of the rubber sound 110. Although this piezometer 150 may be formed in the side face of a cel, since the clay film is in a porous wall and water pressure may be unable to measure, as shown in drawing 3 (B), it is suitable to prepare in a lower limit 110C side side. Moreover, since it is deleted by the sound 110 and soil may adhere while taking down the rubber sound 110 in the bar hole 100 at lower limit side 110C, it is desirable to attach in the inner part of crevice 110D of a lower limit side.

[0027] Next, the test method about the gestalt 2 of operation is explained with reference to drawing 1 . A trial adds a repeated load to the soil layers J1 and J3 of a vertical stage by turns, measures the variation rate on real time, performs the static load test of the middle soil layer J2 after that, and measures static reinforcement. the yield load or the non-liquefying critical load (Pl) which that of the load test of the repeated load to the soil layers J1 and J3 of vertical stage each itself is completely the same as the gestalt 1 of operation, and is expected -- N phase -- dividing -- loading -- every load -- the repeated load of Plus alpha -- n times or predetermined time Tn -- applying -- the variation rate of the foundation -- an amount r is measured and the static reinforcement of the middle soil layer J2 is measured for every repeated-load loading of each phase.

[0028] Hereafter, concrete test procedure is explained. It excavates by Mr. Fukashi of a stratum who should inspect a bar hole 100, and by the drill rod 140, the rubber sound 110 is inserted to the predetermined depth location in a bar hole 100, and it examines in the following procedures.

** the experimental setting rubber sound 110 -- supply the 2nd room of a pressure to 112, load the middle soil layer J2 with a static compressive load, and measure the early age strength of the middle soil layer J2. Specifically, it asks for "Load P - the displacement r curve" in a static condition. The initial pressure P0 by which the rubber sound 1 sticks to a porous wall, and a variation rate is stabilized at this time is ** **. the breaking load or the non-liquefying critical load expected -- Pl -- carrying out -- differential pressure with initial pressure P0 -- N phase -- dividing -- load increment (deltaP) = (Pl-P0) / N -- deciding -- the 1st of the rubber sound 110 -- room 111 -- the 3rd room, to 113, in each load phase, a repeated load is added alternately with n times or fixed time amount Tn, and is examined. before a repeat trial -- the 1st of the rubber sound 110 -- room 111 -- the 3rd room of initial pressure P0 is applied to 113.

[0029] The 1st load phase of the 1st load phase reaches 1st room 111. The 3rd room ** To 113 Load with the repeated load of the magnitude of P0 - P0+alpha alternately n times, and the 1st room of the variation rate of 111, the upper case soil layer J1 corresponding to 113 the 3rd room, and the lower-berth soil layer J3 is measured. The relation between a load and a variation rate is supervised on real time like the gestalt 1 of operation, and data are stored in a computer and are graph-ized. Also in this case, a load phase is made into ten steps and limits a repeated load to for 20 times or 20 seconds. A standup as shown in drawing 3 (E) makes the loading load in this case a rapid impact load. After an impact load starts rapidly, it maintains fixed time amount t0 load, and compresses a soil layer certainly, and a load falls after that. When the 1st room of the 3rd room of a load joins one side of 113 with 111, a load is added to another side by turns so that a load may not be added. Although it has become at the fall initiation time of a load standup before of the load to ** of another side, as the dotted line indicated, it is good also as the load standup time to ** of another side, and coincidence. Shearing force acts on the vertical both ends of the upper case soil layer J1, and the vertical both ends of the lower-berth soil layer J3 with compression, shearing force will act, shaking from the up-and-down soil layers J1 and J3 being especially compressed by turns about the middle soil layer J2 (x mark in drawing 3 (A) - (C)), and the same damage as the time of an earthquake joins a soil layer. Since the 2nd room of the die length L2 of 112 serves as a diameter D grade of the rubber sound 110, the configuration of the rubber sound 110 the phenomenon of resulting in destruction -- suitable -- it can catch -- the 1st, since the 3rd room of the die length L1 and L3 of 111,113 is about 2 times of D Since the rubber members 115A and 115C swell spherically, a variation rate becomes large, and moreover, the component of a force of compressive force can act to the direct middle soil layer J2, and can raise the effect of a load to a soil layer.

** After a repeated-load trial, the 2nd room of a pressure is again supplied to J2, load the middle soil layer J2 with a static compressive load, perform measurement of the middle soil layer J2 on the strength, and obtain the data of how much to have fallen from early age strength. This cycle is made into 1 cycle, and the whole delta P, one by one, it enlarges and examines repeatedly, and a loading load is performed until destruction of a soil layer arises fundamentally. The test-result model of the static strength test of the middle soil layer J2 is shown in

drawing 8 . The graph with which drawing 8 (A) made time amount the static load P which adds an axis of ordinate to the middle soil layer J2, and the axis of abscissa, and drawing 8 (B) are the graphs which made time amount the variation rate r and axis of abscissa of the middle soil layer J2 which was able to add the load for the axis of ordinate. Moreover, drawing 8 (C) thru/or (F) are graphs which show the load of the middle soil layer J2 in each phase and the relation of a variation rate which are shown in drawing 8 (A) and (B). As shown in drawing 8 (A) and (B), the early age strength of the middle soil layer before performing a repeat trial is measured first. Change of the rubber sound 110 of a variation rate [as opposed to / change of a variation rate becomes small conversely by a pressure increasing rapidly, if a pressure is not improved, but only a variation rate becomes large and it sticks to a porous wall until rubber member 115B of 112 sticks the 2nd room to the porous wall of a bar hole 100, reach an initial pressure P0, and / a load] is stabilized. A load is increased to P0+delta in this stable field, a variation rate is detected, and as shown in drawing 8 (C), the load-displacement curve (it is a variation rate about a load and an axis of ordinate in an axis of abscissa) of the middle soil layer of an initial stage is created. Let the inclination of this load-displacement curve be a coefficient of strain. A load is returned to P0 (0) after measurement. Even if it returns a load to P0, since a permanent set remains in the middle soil layer J2, a variation rate does not return to origin. The magnitude of the pressure increment delta should just be extent which makes about [of the amplitude of the repeated load added to the vertical stage soil layers J1 and J3 / 1/several], and the relation between a load and a variation rate understands. Next, after performing the 1st repeat trial to the vertical stage soil layers J1 and J3, the static strength test of the middle soil layer J1 is performed. Even if it puts a pressure, a load does not go up but, as for a load P0, only a variation rate becomes large until rubber member 115B of a rubber sound swells only in the part of the permanent set at the time of initial-pressure measurement. When a permanent set is absorbed, a pressure increases rapidly, change of a variation rate becomes small conversely, and the test initiation load P0 (1) is reached. A load is increased to P0 (1)+delta in this stable field, a variation rate is detected, and the load-displacement curve of the middle soil layer after the 1st repeat trial is created (refer to drawing 8 (D)), and let the inclination of a graph be a coefficient of strain. A load is returned to the test initiation load P0 (1) after measurement. Even if it returns a load to P0 (1), since a permanent set remains in the middle soil layer J2, a variation rate does not return to the variation rate at the test initiation time. Hereafter, the static strength test of the middle soil layer J2 is similarly performed after the repeat trial of the vertical stage soil layers J1 and J3. In an elastic field, the coefficient of strain obtained from a load-displacement curve is almost equal. What time, after that repeat trial (the k-th time), first, that a load increases to (P0(k)+delta) takes time amount, and when the middle soil layer J2 changes into a breakdown condition, after reaching a test initiation load (P0 (k)), the variation rate increases greatly without a load's going up very much. As for the load-displacement curve at this time, inclination becomes sudden (refer to drawing 8 (E)). Furthermore, when the middle soil layer J2 breaks (the m-th drawing has indicated as the next step of a breakdown phase), the load falls as with a peak of a breaking load Pl, and when it descends to existing pressures, such as ground-water pressure, it becomes fixed. A variation rate increases rapidly from near the breaking load (drawing 8 (B)), and a load-displacement curve serves as graphical form to which a variation rate increases further, even if a pressure declines, as shown in drawing 8 (F).

[0030] The data of a variation rate to the data of a variation rate to the repeated load of an upper case and the lower-berth soil layers J1 and J3 and the static load of the middle soil layer J2 are set, the dynamic deformation property over a repeated load is judged, and it asks for reinforcement, such as the yield point and the breaking point. Moreover, if it is assumed that shearing force produces liquefaction of a soil layer in the middle soil layer J2 which acts from the upper and lower sides and liquefaction arises, since the variation rate of the measurement data shown in drawing 8 will become large rapidly, it turns out that liquefaction arose. Moreover, also when the neutral stress by piezometer 150 becomes fixed, liquefaction can be verified and it can verify to a duplex whether liquefaction arose or not. thus -- without it performs a torsion shear test like a gestalt 1 and the shaft-orientations shear trial of operation according to the gestalt 2 of this operation -- the mutual loading of the simple compressive load to the soil layer of a vertical stage -- shearing force -- a middle soil layer -- it can add -- a simple configuration -- certain -- a short time -- and the dynamic trait trial of the soil layer where precision is high can be performed by low cost.

[0031] Although the immobilization section which loads a rubber sound with a static load was prepared with the gestalt 2 of the above-mentioned implementation, only the up-and-down repeated-load loading section may constitute without preparing the immobilization section, and you may take notice of only deformation of a vertical stage soil layer. It is because a vertical stage soil layer will be affected if shearing force is acting on the boundary section of a vertical stage soil layer and liquefaction occurs. Moreover, what is necessary is to be good also as three or more steps of upper and lower sides, and just to prepare the immobilization section in the middle of each repeated-load loading section in that case, although the repeated load was considered as two steps of upper and lower sides.

[0032] it could also load independently, respectively among three loads, the compressive load by which loading is carried out in the direction which intersects perpendicularly with a hole axis as a repeated load, the torsion shear load by which loading is carried out to the hand of cut centering on a hole axis, and the shear load by which loading is carried out to a hole axis and a parallel direction, and at least two kinds of loads were combined -- it can also combine and load.

[0033] In addition, although the gestalten 1 and 2 of the above-mentioned implementation explained taking the case of the case where a bar hole 100 is dug perpendicularly, it is applicable also about the case where it digs aslant when digging horizontally, for example. Moreover, as a cel for measurement, the piston jack which

pressurizes a metal loading plate with oil pressure etc. may be used instead of the rubber sounds 110 and 1, and the suitable cel for measurement is chosen according to a soil layer.

[0034]

[Effect of the Invention] Since it can examine in a original location according to this invention, without taking out an underground sample as explained above, the reinforcement and the deformation property over a repeated load of a soil layer in a natural condition can be searched for. Especially, soil layers where particle size is large, such as a soil layer, a gravel bed, etc. which cannot be sampled, or a weathered rock, and a soft rock can also be measured by mixing of a very loose sand stratum or stones, and the use range spreads. Moreover, to the conventional sample trial, in a short time, since it can examine, it is economical.

[0035] the repeat shearing force of the form which resembled rolling of an earthquake actual in the boundary section of a loading field by loading two or more fields of the direction of a hole axis of the porous wall of a ball ring hole with a compressive load especially repeatedly by turns -- ******** -- things are made and it can examine also about the property over a repeat compressive load, simultaneously the property over shearing force. Since it becomes easy to be generated according to shearing force, liquefaction is effective in the judgment of liquefaction. Since liquefaction will spread also to a compressive-load loading field and a variation rate will change a lot if the boundary section collapses, liquefaction can be judged. Moreover, even when applying a repeated load to one field of the porous wall of a ball ring hole, the property of the various foundations can be examined by the analysis technique of data. In this case, the compressive load by which loading is carried out in the direction which intersects perpendicularly with a hole axis and the torsion shear load by which loading is carried out to the hand of cut centering on a hole axis, By [which combined 1 of three loads of the shear load by which loading is carried out to a hole axis and a parallel direction, or at least two kinds of loads] combining, and loading with and examining a load The trial to a repeated load on which compression and a shear load act and which was based in fact can be performed being twisted.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] Drawing showing liquefaction of the foundation in the original location using the bar hole which drawing 1 (A) requires for the gestalt 1 of operation of this invention, and the outline configuration of a dynamic trait testing device, and drawing 1 (B) are drawings showing the control configuration of a pressure control valve.
[Drawing 2] Drawing 2 (A) is a graph with which drawing showing the example of an output by the pressure control valve of drawing 1 and this drawing (B) show the model of the test result of drawing 1 .
[Drawing 3] Drawing 3 (A) thru/or (E) are the explanatory views showing liquefaction and the dynamic trait test method of the foundation in the original location using the bar hole concerning the gestalt 2 of operation of this invention.
[Drawing 4] Drawing 4 is the functional description Fig. of the rubber sound of drawing 3 .
[Drawing 5] Drawing 5 is the outline block diagram of the rubber sound of drawing 4 .
[Drawing 6] Drawing 6 is the explanatory view showing liquefaction of the foundation in the original location using the bar hole concerning the gestalt 2 of operation of this invention, and the example of a configuration of a dynamic trait testing device.
[Drawing 7] Drawing 7 is other graphs of the test-result model of drawing 1 .
[Drawing 8] Drawing 8 (A) thru/or (F) are graphs which show the test-result model of the static strength test of a middle soil layer.
[Description of Notations]
1 Rubber Sound (Cel for Measurement), 2 Water Tank (Liquid Tank), 3 Water (Liquid),
4 Pressure Feed Zone, 5 Pressure Control Valve, 6 Interconnecting Tube,
7 Computer,
9 torque generator, 10 Displacement detecting element,
11 Shear Load Generator, 12 Displacement Detecting Element
100 Bar Hole
110 Rubber Sound
111,112,113 The 1st, the 2nd, the 3rd room
121,122,123 The 1st, 2nd, and 3rd pressure regulation section
114 Body Section, 115 Rubber Member, 116 Bolting Member
120A A chemical cylinder, 120B Gas holder
121C, 123C Hydraulic cylinder
121D, 123D Bulb
121E, 123E Bulb
122C Water tanks 122C and 122D Pressure control valve
J1 An upper case soil layer, J2 A middle soil layer, J3 Lower-berth soil layer
150 Piezometer

[Translation done.]